S.P. NO. H.009250
ATTACHMENT "A" Geotechnical Services Document

SLOPE STABILITY (Embankment & Excavation)

The Objective of a Slope Stability Analysis is to determine the factor of safety of the proposed embankment or excavation on the project subsurface soils and make appropriate Engineering Design Recommendations. The resistance factors from the AASHTO LRFD Bridge Design Specifications, latest edition, shall be used to analyze slope stability.

Standard Procedure

The embankment/excavation slope stability analysis shall consist of (1) modeling the appropriate boring logs to define the critical embankment/excavation geometry (cross-section) with subsurface soils, (2) interpreting the shear strength test data to determine drained and/or un-drained shear strength design parameters, (3) performing the stability analysis utilizing the Bishop, Spencer, and/or sliding block method deemed appropriate by the engineer, (4) determining the maximum resistance factors for both long- and short-term conditions at the critical fill heights at each bridge end, along the approach embankment (intermediate fill height) and in critical cut sections. Maximum resistance factor should also be taken into consideration for rapid drawdown conditions when applicable, (5) analyzing different methods for mitigating possible stability problems and if necessary, make recommendations for geotechnical instrumentation to monitor stability performance, (6) defining areas of highly erodible materials and analyzing erosion control measures, and (7) preparing a report with all the above information and engineering recommendations.

Deliverables of Slope Stability Analysis shall include the following:

- Printout of critical stability circle and/or block for each design case;
- Geotechnical models (cross-sections) and design input parameters;
- Summary table with critical fill heights and resistance factors, or critical excavation cross-sections with resistance factors;
- Certification that the modeled embankments meet the required long and short-term resistance factors required;
- Summary of alternatives for mitigating possible stability problems with resistance factors and estimated costs;
- Specifications for slope stability mitigation measures;
- Geotechnical Instrumentation Plan (if recommended);
- Recommended erosion control measures; and
- Construction Slope Stability notes for the Bridge General Notes Sheet.

EMBANKMENT SETTLEMENT

The Objective of a Consolidation/Settlement Analysis is to determine the amount of settlement in inches/feet, and the time required for this settlement to take place in days/months/years when the proposed embankment is constructed on the project subsurface soils, and make appropriate Engineering Design Recommendations.

Standard Procedure

The embankment settlement analysis shall consist of (1) modeling the appropriate boring logs to define the critical embankment geometry (cross-section) with subsurface soils, (2) interpreting the consolidation test data to determine design consolidation soil parameters, (3) performing a settlement analysis for the critical bridge end fill heights and for intermediate fill heights as needed, (4) determining the predicted total consolidation settlement, the predicted 90% consolidation settlement and the time periods for the predicted settlement to occur, (5) if the predicted time for 90% of the settlement to occur is excessive (greater than 5 months) recommendations shall be made to reduce the amount of consolidation settlement and/or to accelerate the settlement through the use of lightweight fills, surcharge placement, wick drains or other methods determined by the Engineer, (6) if mitigation is required, the consultant shall include all analyses and information including special provisions relating to surcharge quantities and limits, wick drain information and layouts and settlement monitoring instrumentation details, (7) assess the impact of predicted settlement and recommended mitigation on pavement, culverts, retaining walls and bridge abutments, and (8) preparing a report with all the above information and engineering recommendations.

Deliverables of Consolidation/Settlement Analysis shall include the following:

- Geotechnical models (cross-sections) with design input parameters;
- Printout of settlement analysis for each design case;
- Presentation of settlement analysis in graphical form (Settlement vs. Time of consolidation Curves) with clear indications of total predicted settlement, 90% predicted settlement, and the effect of surcharging and/or placing wick drains. Hand calculations should be included;
- Assessment of the potential impact of predicted settlement and any recommended mitigation on pavement, culverts, retaining walls and bridge abutments;
- Wick Drain Design Sheets;
- Specifications for recommended settlement mitigation measures (surcharge, wick drains, etc.); and
- Construction Settlement notes for the Bridge General Notes Sheet.

BRIDGE FOUNDATIONS:

PILES

The Objective of a Pile Design Analysis is to determine the pile type, pile capacity, lateral load requirements, and pile length for the project subsurface soils considering pile set-up, down-drag (negative skin friction), potential scour, and other project related factors.

Standard Procedure

The Pile Foundation Design Scope of work shall consist of (1) modeling the appropriate deep boring logs and/or Cone Penetration (CPT) sounding data to define the project subsurface soil profile, (2) obtaining Standard Penetration Test (SPT) N-values and interpreting the laboratory test data to determine pile design soil parameters, (3) performing pile static analyses to determine pile type, pile capacity and plan pile tip elevation or length, (4) estimating foundation settlement and "down-drag" loads, (5) performing lateral load analyses, (6) estimating scour depths, (7) performing wave equation analyses to determine pile drivability and hammer approval, (8) assessing constructability issues such as installation sequencing, heave and/or lateral pile movement, installation aids (jetting or augering), etc., (9) performing analyses to develop test pile recommendations (feasibility, location, test pile tip elevation, etc.), and pile driving analyzer (PDA) recommendations.

(The consultant shall utilize approved pile capacity prediction methods or software. The "PILECPT" software provided by the LTRC Web site shall be utilized with the CPT sounding data.)

Deliverables for Pile Foundation Design Analysis shall include the following:

- Design spreadsheets or calculations indicating the geotechnical design parameters utilized for each boring log, including scour elevations if applicable, for the pile type selected;
- Graphical or tabulated representation of the pile capacity vs. tip elevation (not depth of penetration);
- If the FHWA software Driven 1.2 is used, include an electronic copy of the data file generated along with a hard copy of the input and output;
- Lateral load analyses;
- Recommended plan pile tip elevations for all bents. (Shown in the pile data sheet.);
- Feasibility study for utilizing a test pile (static resistance factors vs. dynamic resistance factors);
- Drivability recommendations;
- Pile installation criteria with discussion of installation issues;
- Pile Driving Analyzer (PDA) recommendations;
- Hammer approval method recommendations;

- Necessary pay items and corresponding quantities for test piles, indicator piles, and monitor piles;
- Special Provisions for Dynamic Monitoring and Dynamic Analysis, if recommended for project;
- Special Provision for Static Load Test, if recommended for project;
- Considerations for "down-drag" effects on piles;
- Considerations for pile "set-up;"
- Uplift Capacity of Group Piles if required by project conditions; and
- Pile notes for the Bridge General Notes Sheet.

DRILLED SHAFTS

The Objective of a Drilled Shaft Analysis Design is to determine the diameter, tip elevation and installation procedure for the project subsurface soil conditions.

Standard Procedure

The Drilled Shaft Foundation Design Scope of work shall consist of (1) modeling the appropriate deep boring logs and/or Cone Penetration (CPT) sounding data to define the project subsurface soil profile, (2) obtaining Standard Penetration Test (SPT) N-values and interpreting the laboratory test data to determine drilled shaft design soil parameters, (3) selecting appropriate design equations for the project soil types to determine ultimate base and side resistance and selecting appropriate resistance factor, (4) performing axial and lateral load analyses to determine drilled shaft diameter and tip elevation, and (5) performing analyses to determine appropriate Construction Method for project soil conditions.

Deliverables for Drilled Shaft Foundation Analysis and Design shall include the following:

- Design spreadsheets or calculations indicating the geotechnical design parameters utilized for each boring log including scour elevations if applicable;
- Graphical or tabulated representation of the drilled shaft capacity vs. tip elevation for each diameter;
- Lateral load analyses;
- Considerations for "down-drag;"
- Recommended plan drilled shaft diameters and tip elevations for all bents. (Shown in the Drilled Shaft data sheet);
- Recommended Construction Method with discussion of installation issues;
- Drilled Shaft notes for the Bridge General Notes Sheet;
- Special Provision for Integrity Testing if required for project; and
- Special Provision for drilled shaft Load Test if required for project.

OTHER FOUNDATIONS

If other types of foundation are recommended for the specific project conditions, the Standard Procedure format and the Deliverables format outlined for piles and drilled shafts shall be followed with specific design details for the type of Foundation recommended.

PILE SUPPORTED APPROACH SLAB DESIGN DATA

The DOTD normally uses a timber pile supported approach slab to minimize differential settlement in the transition zone between the approach embankment and the bridge abutment.

Deliverables for Pile Supported Approach Slabs shall include the following:

- Layout showing pile locations;
- Pile diameter and length; and
- Drivability Recommendations.

BRIDGE FOUNDATION LOAD TEST PROGRAM

If the project subsurface conditions are difficult, significant uncertainties exist in the Foundation Design, and if cost savings can be predicted, a Foundation Load Test Program may be appropriate. Depending on project conditions, a Foundation Load Test Program may be included either in the Design or in the Construction phase.

Deliverables for the Foundation Load Test Program shall include the following:

- Location and Type of Load Test Proposed;
- Design of Test Foundation (pile, drilled shaft, or other);
- Dynamic Test Procedures and Schedules;
- Load Increment Requirements;
- Maximum Test Load;
- Instrumentation Requirements;
- Load Test Layout and Design Sheets for Plans;
- Special Provision for Construction of Test Foundation and Conduct of Load Test;
- Interpretation of Load Test Results and Recommendations; and
- Foundation Load Test Report.

EARTH RETAINING STRUCTURES

A Retaining Wall is normally required if adequate space (r-o-w) is not available for a Slope. The DOTD has used Mechanically Stabilized Earth (MSE) Walls, Gravity Concrete Walls, Sheet Pile Walls, plus other types for transportation projects. The selection of the most appropriate Retaining Wall type for the specific project requirements and site and subsurface conditions can have profound effects on the project cost and constructability.

General Considerations

Every Retaining Wall type has a unique design procedure and generally requires the services and coordination of a Geotechnical Engineer and a Structural Engineer. The following criteria are generally required for analysis and design of all Retaining Wall types:

Deliverables for all Retaining Wall Analyses and Designs shall as a minimum include the following:

- Earth Pressure Distributions;
- Bearing Capacity of the foundation soil or rock;
- Analyses for Sliding and Overturning and Mitigation Recommendations;
- Settlement and Tilt (Rotation) Analyses and Mitigation Recommendations;
- Drainage Recommendations;
- Global Stability Analyses and Mitigation Recommendations;
- Backfill Properties;
- Wall Components/Materials;
- Wall Construction Procedures;
- Wall Layout with plan view, elevation view, typical sections, and details;
- Quantities Table with applicable General Notes;
- Design Life; and
- Special Provisions.

MECHANICALLY STABILIZED EARTH (MSE) WALLS

The AASHTO LRFD Bridge Specifications, latest edition as well as all supplements shall be followed for analysis and design of all MSE Walls. FHWA NHI-10-024 Vol. I and NHI-10-025 Vol. II, "Design of MSE Walls and Reinforced Slopes" (Berg et al., 2009) may be used as a reference.

Additional Deliverables for MSE Walls shall be required to identify the MSE specific design and construction requirements:

- Type and Size of Facing Element;
- Type, Size and Design Length of Reinforcement Elements;

- Type of Connections;
- Minimum embedment requirements;
- Backfill Material Requirements; and
- If TEMPORARY WALL, identify specific requirements.

CONCRETE WALLS

Cast-In-Place Concrete Gravity or Cantilever Walls are now generally limited to small applications or specialized situations because of the development of more economical wall types. Standard design and construction procedures are well documented in many geotechnical books and other publications.

Deliverables for Concrete Walls are as outlined under General Considerations above.

SHEET PILE WALLS

The resistance factors from the AASHTO LRFD Bridge Design Specifications, latest edition, shall be used to design sheet pile walls.

Additional Deliverables for Sheet Pile Walls shall be as outlined in the DOTD Guidelines:

- Sheet Pile Section and Type;
- Minimum Section Modulus;
- Minimum Depth of Penetration;
- Moment of Inertia Requirements;
- Estimated long and short term Deflections;
- Anchor Loads;
- Long and short term Stability including Drawdown and Liquefaction;
- Complete Design Details of sheet piling, Backfill, Drainage, and Connections;
- Corrosion Protection Measures; and
- Construction Constraints.

OTHER RETAINING WALL TYPES

Other types of Retaining Walls that may be appropriate for DOTD transportation projects are Drilled Shaft Walls, Soldier Pile & Lagging Walls, Slurry Walls, Anchored (Tied-back) Walls, Soil Nailed Walls, Reticulated Micro-Pile Walls, Jet-Grouted Walls, and Deep Soil Mixing Walls. These walls shall be designed using generally recognized design procedures applicable to the specific type of wall used.

GEOTECHNICAL ANALYSIS & DESIGN RECOMMENDATIONS REPORT

No standard report format is required and the Consulting Firm may use its own format. However, the GEOTECHNICAL ANALYSIS & DESIGN RECOMMENDATIONS REPORT shall

contain a Background Description of THE PROJECT such as location, geological irregularity, if exists, engineering features and requirements, etc., and shall include all the items listed under Deliverables above that are a part of THE PROJECT.

LIST OF PUBLISHED GEOTECHNICAL DOTD REPORTS AND FORMS PLUS OTHER TECHNICAL REFERENCES

Most of the following can be obtained at the DOTD web site (www.dotd.state.la.us) or at the FHWA Bridge/Geotechnical web site (www.fhwa.dot.gov/bridge).

DOTD Reports and Forms:

- AASHTO LRFD Bridge Design Specifications, latest edition and supplements;
- Standard Specification, latest edition;
- Bridge Manual;
- Road Design Manual;
- Hydraulics Manual;
- Materials Sampling Manual;
- Materials Testing Procedures Manual;
- Drilled Shaft Foundation Construction Inspection Manual (1/08/02);
- LTRC "PILECPT" Software;
- FHWA "DRIVEN" Software;
- Pile and Driving Equipment Data Form (06/19/06);
- Deep Soil Boring Request and Field & Laboratory Request Form (1/03/02) (in one sheet);
- Wick Drain Design Sheets; and
- DOTD Testing Procedures Guidelines For Standard Format.

Other Technical References:

The DOTD has used the following as technical references and guidelines in the design and construction monitoring of Geotechnical features for DOTD projects in the past and are recommended for use by the Geotechnical Engineering Consultant community. This list is not all-encompassing and other publications may be used and referenced. Additions will be made as this Document is updated.

- Subsurface Investigations Manual, Publication No. FHWA HI-97-021, Nov. 1997;
- Manual On Subsurface Investigations, Published by AASHTO, 1988;
- AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, PART I – SPECIFICATIONS and PART II – TESTS, current edition;
- ASTM Procedures and Regulations, current edition;

- Earth Retaining Structures, Participants Manual, FHWA-NHI-99-025, 1999;
- Earth Retaining Systems, Geotechnical Engineering Circular No. 2, Publication No.FHWA-SA-96-038, February 1996;
- Design of MSE Walls and Reinforced Slopes, FHWA NHI-10-024 Vol. I and NHI-10-025 Vol. II, 2009;
- Geotechnical Instrumentation Manual, Publication No. FHWA HI-98-034, October 1998;
- Drilled Shafts: Construction Procedures and LRFD Design Methods, Publication No. FHWA-NHI-10-016, May 2010;
- Soils and Foundations Workshop Manual, Publication No. FHWA NHI-00-045, August 2000;
- Geosynthetic Design and Construction Guidelines Manual, Publication No. FHWA HI-95-038, April 1998;
- Ground Improvement Technical Summaries, DP 116, Publication No. FHWA-SA-98-086;
- Design and Construction of Driven Pile Foundations Reference Manual, Volumes 1 & 2, Publications No. FHWA-NHI-05-042 and FHWA-NHI-05-043, 2006;
- Soil Nail Walls, Geotechnical Engineering Circular No. 7, Publication No.FHWA-IF-03-017,March 2003;
- Soil Nailing Field Inspectors Manual, (DP 103), Publication No. FHWA-SA-93-068, April 1994.